Occupational exposure assessment using antibody levels: exposure to avian leukosis/sarcoma viruses in the poultry industry

Kyung-Mee Choi [a] & Eric S. Johnson [b]

[a] Departments of Environmental and Occupational Health Sciences

[b] Departments of Epidemiology, Health Science Center, University of North Texas, Fort Worth, Texas, USA

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis
Taylor & Francis Group

Occupational exposure assessment using antibody levels: exposure to avian leukosis/sarcoma viruses in the poultry industry

Kyung-Mee Choi[a]* and Eric S. Johnson[b]

Departments of [a]*Environmental and Occupational Health Sciences; [b]Epidemiology, Health Science Center, University of North Texas, Fort Worth, Texas, USA*

Avian leukosis/sarcoma viruses (ALSV) infect and cause cancers in chickens. Poultry workers are exposed to ALSV and other infectious agents in the workplace. This study examines if industrial hygiene assessment of antibody levels in poultry workers can identify risky job tasks at the higher exposure risk to an infectious agent, i.e., ALSV. We compared ALSV antibody levels in poultry workers and control subjects. Occupational and demographic factors were examined for an association with the exposure risk in poultry workers. We found that the antibody levels were significantly higher in poultry workers than in control subjects. Job category and age together were significantly associated with the antibody levels in workers. Certain job tasks were identified with significantly higher antibody levels as compared to others, implying that recommendations should be made to protect workers at these jobs. The findings of this study indicate that the measurement of antibody levels in workers can be useful for industrial hygiene assessment of exposure to infectious agents.

Keywords: occupational exposure; microbial agents; ALSV; antibody levels; poultry workers

Introduction

Avian leukosis/sarcoma viruses (ALSV) are a group of retroviruses that commonly infect and cause cancers in chickens. The acute transforming form of these viruses is among the most potent cancer-causing agents known in animals, since they can cause cancers in chickens within a week of infection (Johnson 1994). Exposure to ALSV is widely prevalent in poultry workers and in the general population (Johnson et al. 1995; Choudat et al. 1996). Virtually all workers in poultry slaughtering and processing plants are exposed. Poultry workers have a high frequency of cuts, scrapes, wounds, and dermatitis from irritant body fluids such as enzymes. These breaches in the skin integrity provide a ready route for these agents to enter the body. Similarly, penetrating wounds from contaminated sharp knives and bone splinters also provide another means of transmission. As typical of occupational exposures, large variations in the degree of workplace exposure to these agents are expected, varying from the unexposed to the most exposed workers, depending on the tasks they perform.

---

*Corresponding author. Email: kchoi@hsc.unt.edu

The literature is replete with assessment of exposure to chemical and physical agents in the workplace (Levy et al. 2006), but there is little on the assessment of exposure to biological agents, particularly microbial agents. Industrial hygiene exposure assessment to microbial agents is often limited to the assessment of airborne exposure by area sampling (Mehta et al. 2008; Spaan et al. 2008; Gora et al. 2009). This method does not unequivocally determine whether or not individual workers have actually been exposed, and potentially may be associated with considerable misclassification of exposure. The use of a biomarker such as the measurement of antibody levels in workers against infectious agents in blood, may potentially offer an advantage over area sampling, and an alternative reliable method of industrial hygiene assessment of exposure at the individual level. To investigate this, we analyzed ALSV antibody levels in poultry workers and general population subjects.

Material and methods

We analyzed ALSV antibody levels in poultry workers who previously worked in a chicken slaughtering and processing plant, and in control subjects. Blood samples were previously collected in a study by Johnson et al. (1995) and ALSV antibodies measured using an Enzyme-Linked Immunosorbent Assay (ELISA). This study was approved by the Human Subjects Institutional Review Board of the National Institute of Environmental Health Sciences, National Institutes of Health, which supported the study. The ELISA used in the study was a whole virus-based test for detecting antibody to ALSV in human sera that was developed by modifying a commercial ELISA kit for detecting ALSV antibodies in chickens manufactured by IDEXX, Portland, Maine. Three separate ELISA tests were conducted on the same serum sample from each individual on different occasions, and the mean absorbance of these three runs was taken as the final ELISA result for the individual. The coefficient of variation of the test for detecting antibodies in chicken serum was $\leq 5\%$, and the accuracy $\geq 95\%$; the specificity was 99.51% and sensitivity 100%. These values were not available for use of the assay on human sera.

Forty-five poultry workers were identified from a local union belonging to United Food and Commercial Workers (UFCW) International Union in Washington, DC. They were recruited by placing advertisements in the union offices. Information collected on poultry workers was restricted to name, sex, race, date of birth, duration of employment, and task performed in the plant. A control group of 44 subjects was separately sampled from the general population, matched roughly on sex, race and age. These control subjects were recruited through advertizing in local newspapers. To be eligible as a control, subjects should not have had a history of having ever worked in a job where exposure to poultry or poultry products occurred.

We identified 28 job titles representing the last jobs held by the poultry workers in the plant. We grouped the job titles into eight categories based on job descriptions listed in the union and employer contract agreement (Table 1). As a surrogate for ALSV exposure duration, we used employment duration grouped as short term (≤ 10 years), mid-term (11–20 years), and long-term (≥ 21 years). Study subjects were separated almost evenly over three age groups: ≤ 30 years old, 31–40 years old, and ≥ 41 years old. Nearly all of the study subjects were black except three, hence race was not further considered. We estimated relative risk for high levels of ALSV antibodies in poultry workers as compared to control subjects, and identified

Table 1.   Description of job categories.

Job category	Description
Cut-up	Line worker who cuts chickens
Cut heart & liver	Worker that cleans, cuts and separates liver, gizzards and oil bag, or who operates the machine that cuts and cleans hearts and livers
Eviscerator	Worker who draws or pulls the guts out, in the main production line, or while assisting the USDA (United States Department of Agriculture) inspectors, or who pulls the crow, or who maintains, changes, and cleans the machine that pulls guts;
Hang-chickens	Workers who hang live chickens or work as fork lift operators who unload crates of live chickens, and set up chickens for hanging
Panners	Workers who take out feathers off chickens
Plant-wide	Utility worker or reliever who does everything plant-wide, such as knife sharpening, clean-up, stacks and hangs chickens, picks up condemned chickens, checks chickens, trims, washes and draws chickens, etc.
Post-evisceration	Wrap giblets and livers, chiller operator, stuffing chickens, and weigh chickens, helps load boxes
Trimmer	Trimmer (also called de-boner) is one who trims chickens

whether demographical and employment factors were associated with the risk. We also investigated the job categories that were taken by the poultry workers whose antibody levels were so high as to be within the upper quartile range of the antibody distribution for the whole poultry workers in this study. By using a generalized linear model (McCullagh and Nelder 1989), the expected mean antibody levels were predicted that were accounted for by the demographical and employment factors of poultry workers. Using the Bonferroni adjustment for multiple comparisons (Kleinbaum et al 1998), the expected mean antibody levels for specific demographical factors and employment conditions were compared to each other. Statistical analyses were performed using SPSS (release 17.0.2).

Results

The distribution of antibody levels was positively skewed for poultry workers (p value = 0.001), while it was not skewed for control subjects (Figure 1). Descriptive statistics for the antibody levels are summarized by gender and age group, respectively, for poultry workers and control subjects (Table 2). As compared to the control subjects, the poultry workers had consistently higher antibody levels in each of the statistics in the table. In particular, the median antibody level in poultry workers, 0.121 was even higher than the upper quartile antibody level in control subjects, 0.110. Within the poultry workers, these antibody statistics were consistently higher in females than in males. We found a significant linear correlation between employment length in years and age in years. The linear correlation coefficient (ρ) was 0.763 (p value 0.000). It is worth noting for age group in Table 2 that the oldest age group ($\geq$41 years) had the highest mean and median antibody levels in poultry workers, but had the lowest in control subjects. The antibody levels also increased with duration of employment in poultry workers. In Table 3, the antibody levels were generally higher than overall mean level in certain job categories ("Cut heart & liver", "Plant-wide", "Eviscerator", "Post
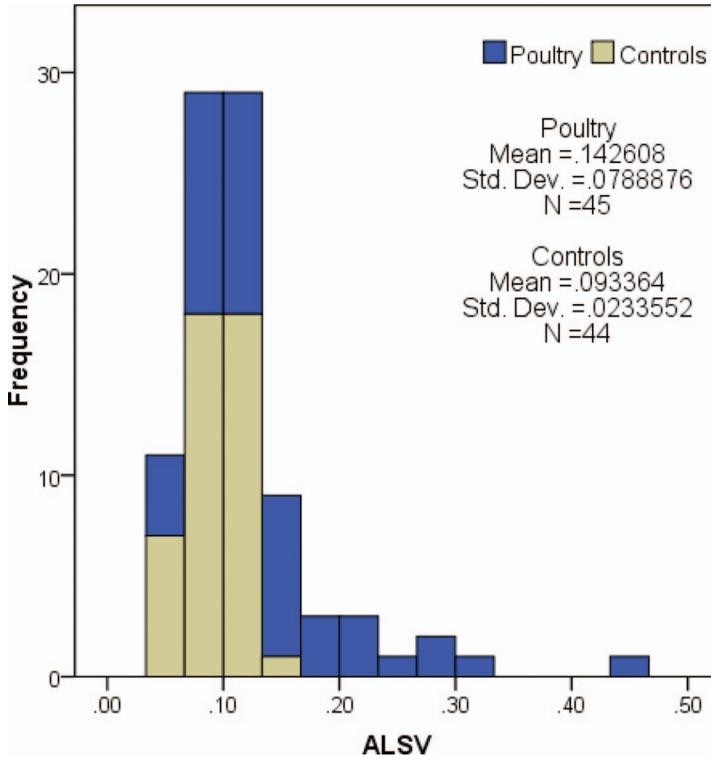
Figure 1.   Histogram of ALSV antibody levels for poultry workers and control subjects.

Table 2.   Distribution of ALSV antibody levels by gender and age comparing between poultry workers and control subjects.

	n	Mean	Median	SD	Minimum	Maximum
Poultry						
Sex						
Male	13	0.1147	0.1107	0.0500	0.0520	0.2553
Female	32	0.1539	0.1338	0.0861	0.0530	0.4493
Age						
≤30 years old	14	0.1252	0.1180	0.0365	0.0763	0.2247
31–40 years old	17	0.1502	0.1247	0.1017	0.0520	0.4493
≥41 years old	14	0.1508	0.1327	0.0808	0.0667	0.3073
Total	45	0.1426	0.1207	0.0789	0.0520	0.4493
Controls						
Sex						
Male	12	0.0996	0.0993	0.0184	0.0700	0.1327
Female	32	0.0910	0.0900	0.0248	0.0427	0.1340
Age						
≤30 years old	19	0.0907	0.0947	0.0203	0.0467	0.1277
31–40 years old	14	0.1023	0.1045	0.0260	0.0657	0.1340
≥41 years old	11	0.0867	0.0873	0.0235	0.0427	0.1157
Total	44	0.0934	0.0950	0.0234	0.0427	0.1340

Table 3. Distribution of ALSV antibody levels in poultry workers by job category and employment duration (Job categories are in the descending order of job category totals in maximum).

Job category		n	Mean	Median	SD	Minimum	Maximum
Cut heart & liver	Total	6	0.2111	0.1860	0.1269	0.0707	0.4493
	Sex Female	6	0.2111	0.1860	0.1269	0.0707	0.4493
	Age 31–40 years old	3	0.2832	0.2160	0.1447	0.1843	0.4493
	≥41 years old	3	0.1389	0.1583	0.0609	0.0707	0.1877
Plant wide	Total	11	0.1470	0.1343	0.0705	0.0530	0.3073
	Sex Male	5	0.1204	0.1257	0.0227	0.0840	0.1427
	Female	6	0.1692	0.1655	0.0907	0.0530	0.3073
	Age ≤30 years old	4	0.1169	0.1205	0.0247	0.0840	0.1427
	31–40 years old	6	0.1403	0.1497	0.0604	0.0530	0.2267
	≥41 years old	1	0.3073	0.3073	.	0.3073	0.3073
Eviscerator	Total	8	0.1493	0.1130	0.0816	0.0623	0.2777
	Sex Male	1	0.0987	0.0987	.	0.0987	0.0987
	Female	7	0.1565	0.1247	0.0854	0.0623	0.2777
	Age ≤30 years old	1	0.1633	0.1633	.	0.1633	0.1633
	31–40 years old	5	0.1329	0.1013	0.0839	0.0623	0.2777
	≥41 years old	2	0.1830	0.1830	0.1212	0.0973	0.2687
Post evisceration	Total	5	0.1429	0.1427	0.0814	0.0640	0.2553
	Sex Male	2	0.1610	0.1610	0.1334	0.0667	0.2553
	Female	3	0.1308	0.1427	0.0617	0.0640	0.1857
	Age ≤30 years old	1	0.1427	0.1427	.	0.1427	0.1427
	31–40 years old	1	0.0640	0.0640	.	0.0640	0.0640
	≥41 years old	3	0.1692	0.1857	0.0954	0.0667	0.2553
Panners[a]	Total	2	0.1507	0.1507	0.1047	0.0767	0.2247
	Sex Male	1	0.0767	0.0767	.	0.0767	0.0767
	Female	1	0.2247	0.2247	.	0.2247	0.2247
	Age ≤30 years old	1	0.2247	0.2247	.	0.2247	0.2247
	≥41 years old	1	0.0767	0.0767	.	0.0767	0.0767
Trimmer[a]	Total	5	0.1077	0.1033	0.0330	0.0763	0.1627
	Sex Female	5	0.1077	0.1033	0.0330	0.0763	0.1627

(continued)

Table 3. (*Continued*).

			n	Mean	Median	SD	Minimum	Maximum
	Age	≤30 years old	2	0.0898	0.0898	0.0191	0.0763	0.1033
		≥41 years old	3	0.1197	0.1070	0.0383	0.0893	0.1627
Cut up[a]	Total		3	0.1051	0.1097	0.0225	0.0807	0.1250
	Sex	Female	3	0.1051	0.1097	0.0225	0.0807	0.1250
	Age	≤30 years old	2	0.1173	0.1173	0.0108	0.1097	0.1250
		31–40 years old	1	0.0807	0.0807	.	0.0807	0.0807
Hang chickens	Total		5	0.0941	0.1087	0.0283	0.0520	0.1207
	Sex	Male	4	0.0980	0.1097	0.0311	0.0520	0.1207
		Female	1	0.0783	0.0783	.	0.0783	0.0783
	Age	≤30 years old	3	0.1133	0.1107	0.0064	0.1087	0.1207
		31–40 years old	1	0.0520	0.0520	.	0.0520	0.0520
		≥41 years old	1	0.0783	0.0783	.	0.0783	0.0783
Employment duration								
≤10 years	Total		17	0.1200	0.1153	0.0389	0.0640	0.2267
	Sex	Male	6	0.1148	0.1180	0.0174	0.0840	0.1343
		Female	11	0.1228	0.1097	0.0474	0.0640	0.2267
	Age	≤30 years old	11	0.1159	0.1153	0.0245	0.0763	0.1633
		31–40 years old	5	0.1214	0.1013	0.0644	0.0640	0.2267
		≥41 years old	1	0.1583	0.1583	.	0.1583	0.1583
11–20 years	Total		11	0.1394	0.1247	0.0690	0.0520	0.2553
	Sex	Male	5	0.1319	0.1107	0.0763	0.0520	0.2553
		Female	6	0.1456	0.1453	0.0690	0.0530	0.2247
	Age	≤30 years old	3	0.1593	0.1427	0.0588	0.1107	0.2247
		31–40 years old	6	0.1184	0.1117	0.0647	0.0520	0.2160
		≥41 years old	2	0.1723	0.1723	0.1174	0.0893	0.2553
≥21 years[a]	Total		17	0.1673	0.1627	0.1069	0.0623	0.4493
	Sex	Male	2	0.0717	0.0717	0.0071	0.0667	0.0767
		Female	15	0.1801	0.1650	0.1076	0.0623	0.4493
	Age	31–40 years old	6	0.2059	0.1747	0.1407	0.0623	0.4493
		≥41 years old	11	0.1462	0.1070	0.0836	0.0667	0.3073

[a] Information unavailable in some specific sub-categories.

evisceration'' and ''Panners''). Particularly, the highest antibody level (i.e., 0.4493) in the entire study subjects was observed in a female poultry worker. She was in the age group of 31–40 years old, and had worked longer than 20 years in a job task belonging to the category ''Cut heart & liver''.

Table 4 shows the relative risk for demographical factors and employment conditions, respectively. Compared with the control subjects, a significantly increased relative risk of 2.81 was observed for poultry workers to have antibody levels higher than 0.110, the upper quartile level in the antibody distribution of control subjects. The relative risk for female poultry workers, 3.09 was higher than the risk for male poultry workers, 2.12. Almost half (47%) of the female poultry workers had long-term employment at the poultry plant. In contrast, almost half (46%) of the male poultry workers had the short-term employment at the plant. Only 15% of male poultry workers had the long-term employment. The relative risks did not differ much by age group, and in each age group the relative risk was significant. Similarly, the relative risks did not differ much by duration of employment, although risk appears slightly lower in the short-term employment (≤10 years). The relative risk in each duration of employment was statistically significant. Among the job categories, the highest relative risk was found for ''Cut heart & liver'' followed by ''Plant wide'', ''Post evisceration'' and ''Evisceration'', and each of them was statistically significant. This is consistent with the findings in Table 3 for the job categories that had the highest mean antibody levels.

In addition, we examined the upper quartile range of antibody distribution in poultry workers, that includes the antibody levels higher than 0.175. Surprisingly, none of the control subjects had such high levels of antibodies for this range. More

Table 4. Relative risks (RR) for higher ALSV antibody levels than 0.110 in poultry workers as compared to control subjects (job categories are in the descending order of RR).

	RR	95% CI Lower	95% CI Upper	Pearson Chi-square Asymp. Sig. (2-sided)
Sex				
Male	2.115	0.834	5.364	0.126
Female	3.094[a]	1.540	6.213	0.001
Age				
≤30 years old	2.750[a]	1.215	6.224	0.018
31–40 years old	2.912[a]	1.347	6.292	0.007
≥41 years old	2.750[a]	1.215	6.224	0.018
Employment length				
≤10 years	2.588[a]	1.158	5.786	0.022
11–20 years	3.000[a]	1.312	6.859	0.013
≥21 years	2.912[a]	1.347	6.292	0.007
Job category				
Cut heart & liver	4.583[a]	2.227	9.433	0.001
Plant wide	3.500[a]	1.621	7.557	0.002
Post evisceration	3.300[a]	1.275	8.544	0.034
Eviscerator	2.750[a]	1.080	7.000	0.049
Panners	2.750	0.601	12.587	0.267
Cut up	1.833	0.329	10.225	0.519
Trimmer	1.100	0.171	7.078	0.921
Hang chickens	1.100	0.171	7.078	0.921
Overall	2.811[a]	1.412	5.598	0.001

[a]5% level of significance.

than 90% of the poultry workers in this range were respectively summarized as females, older than 30 years, and had duration of employment longer than 10 years. They were either one of four job categories, "Cut heart & liver", "Plant wide", "Post evisceration", and "Evisceration". These upper range results are consistent with those for mean antibody levels (Table 3), and relative risks (Table 4).

Next, we predicted the expected mean antibody levels of poultry workers by applying a generalized linear model for the ALSV antibody levels distributed by Gamma distribution. The antibody levels were initially fitted by a two-way full factorial model with gender, age group, employment duration, and job category. We found that neither employment duration nor age group were significant in the model. However, age group had a significant interaction effect with job category in the model. A significant linear correlation was observed between employment length in years and age in years. Partly due to the limited sample size, no significant interaction effects were observed other than between age group and job category. With overall significance (*p* value 0.014) we found a final model that included gender, age group, and job category each as the main effect and an interaction effect between age group and job category. Gender and age group were not significant main effects on accounting for the variation of the antibody levels, but they were included in the final prediction model, because the other models without them did not make much difference in model fit. However, duration of employment was not included in the final prediction model, because overall significance was not obtained with it in the model. In the final model, job category (*p* value 0.001) and interaction between job category and age group (*p* value 0.007) appeared to be significant each in accounting for the antibody variation among the poultry workers. Thus, antibody levels of poultry workers were predicted using the final model that had gender, age group and job category each as the main effect and an interaction effect between age group and job category. Table 5 shows the marginal expected mean antibody levels, respectively by gender, age group, and job category. The table also shows the expected mean antibody levels, specifically for each age group in various job categories, except the job category "Cut heart & liver" among the workers in ages for ≤30 years, "Trimmer" and "Panners" for ages between 31 and 40 years, and "Cut up" for ages ≥41 years. Prediction was not made for the conditions of no available data.

For multiple comparisons over the predicted mean antibody levels, we used *Bonferroni* adjustment at the 5% overall significance. A significant difference was found between the job categories "Cut heart & liver" and "Post evisceration" among the workers in age group of 31–40 years (*p* value 0.035). Among this age group of 31–40 years, poultry workers in the job category "Cut heart & liver" are expected to have higher mean antibody level by 0.2192 (95% CI, 0.0054 and 0.4330) than the other workers in the job category "Post evisceration". It was also expected that workers in job category "Cut heart & liver" had higher mean antibody level by at least 0.1 than the workers in three other job categories, "Cut up", "Trimmer", and "Hang chickens". In particular, compared to the job category "Hang chicken" that had the lowest antibody level both in the minimum and maximum (Table 2), it is expected the workers in "Cut heart & liver" to have significantly higher mean antibody level by a difference 0.1127 (*p* value 0.022). No other significant difference was identified in the expected mean antibody levels.

Table 5.   The marginal expected mean levels of ALSV antibodies predicted by a generalized linear model (job categories are in the descending order of the marginal mean levels).

	Mean	Std. Error	95% Wald Confidence Interval	
			Lower	Upper
Sex				
Male	0.1205	0.0234	0.0747	0.1663
Female	0.1462	0.0120	0.1227	0.1696
Age				
≤30 years old	0.1328	0.0174	0.0987	0.1669
31–40 years old	0.1185	0.0141	0.0910	0.1461
≥41 years old	0.1466	0.0195	0.1084	0.1848
Job category (for all ages)				
Cut heart & liver	0.1982	0.0337	0.1322	0.2642
Plant wide	0.1857	0.0354	0.1163	0.2552
Eviscerator	0.1482	0.0271	0.0951	0.2013
Post evisceration	0.1182	0.0218	0.0755	0.1609
Panners	0.1507	0.0396	0.0730	0.2283
Trimmer	0.0919	0.0214	0.0501	0.1338
Cut up	0.0862	0.0242	0.0388	0.1335
Hang chickens	0.0855	0.0136	0.0588	0.1122
Job category for age ≤30 years old				
Panners	0.2118	0.0764	0.0622	0.3615
Eviscerator	0.1505	0.0564	0.0400	0.2610
Post evisceration	0.1298	0.0498	0.0323	0.2274
Plant wide	0.1297	0.0243	0.0821	0.1774
Hang chickens	0.1262	0.0262	0.0748	0.1776
Cut up	0.1045	0.0313	0.0432	0.1658
Trimmer	0.0770	0.0257	0.0267	0.1274
Cut heart & liver[a]				
Job category for age 31–40 years old				
Cut heart & liver	0.2704	0.0565	0.1597	0.3811
Plant wide	0.1329	0.0201	0.0936	0.1723
Eviscerator	0.1240	0.0212	0.0824	0.1655
Cut up	0.0678	0.0306	0.0079	0.1278
Hang chickens	0.0648	0.0226	0.0205	0.1092
Post evisceration	0.0512	0.0258	0.0006	0.1018
Trimmer[a]				
Panners[a]				
Job category for age ≥41 years old				
Plant wide	0.2945	0.1036	0.0915	0.4975
Post evisceration	0.1736	0.0331	0.1088	0.2384
Eviscerator	0.1702	0.0456	0.0809	0.2595
Cut heart & liver	0.1261	0.0304	0.0664	0.1857
Trimmer	0.1068	0.0272	0.0534	0.1602
Panners	0.0895	0.0294	0.0318	0.1471
Hang chickens	0.0655	0.0299	0.0069	0.1241
Cut up[a]				
Overall	0.1333	0.0116	0.1107	0.1560

[a]Data were unavailable for the specific sub-category.

Discussion and conclusion

Workers in the poultry industry have been at one of the highest risks of human exposure to a wide variety of microbial agents found in poultry. However, to our

knowledge, there has not been any systematic industrial hygiene assessment on the extent of exposure to these agents in the industry. We conducted a Medline search of the literature for the period from 1950–2009 using the following search terms – bacteria, bacterial infections, communicable diseases, exposure, infection, infectious agents, occupational, occupational diseases, occupational exposure, occupational exposure assessment, occupational health, virus diseases, and viruses. Out of a total of 1,195 references, the search found only two studies that used antibody levels (*Brucella* antibodies by Yoo et al. 2009; and *Pseudomonas pseudoalcaligenes* antibodies by Mattsby-Baltzer et al. 1989), to characterize occupational exposure to microbial agents. These two studies considered the association between employment duration and antibody levels, but they did not further examine tasks or job categories as we have done in this study. This indicates that the use of antibody levels to characterize industrial hygiene assessment has been sparsely utilized.

Although this study was limited by small sample size, the study results indicate that measurement of antibody levels may be useful for industrial hygiene assessment of exposure to infectious agents. First, it showed that certain high levels of antibodies (i.e., the upper quartile range in the antibody distribution of poultry workers) may be discriminated between occupational exposures and background exposures. Next, it was shown that the measurement of antibody levels has the potential of identifying jobs at high risk of exposure. In addition to job tasks, it was also shown that antibody levels can be useful for identifying occupational determinants of exposure (e.g., exposure duration) and demographical characteristics that could be associated with higher exposure risk. Due to the nature of job tasks, they may be associated with demographical characteristics, such as long-term employment than the shorter term, more females than males, or combination of these.

Limitations in our study include its small sample size, the delay in collecting blood samples (within six months of the plant closing down), and the lack of information on confounding factors such as tobacco smoking. Thus, caution should be exercised in interpreting the findings. In spite of the limitations, the study identified certain high risk jobs for certain age groups and gender in poultry slaughtering & processing plants. Its practical implication is the possible use of this method in making recommendations for protecting workers in performing these jobs. The underlying purpose of the study was to call attention to the possible use of antibodies in industrial hygiene assessment of exposure to infectious agents, and to provide preliminary data. Large-scale studies should be followed for more accurate assessment, and the role of potential occupational and non-occupational confounding factors can be examined in greater detail.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

Choudat D, Dambrine G, Delemotte B, Coudert F. 1996. Occupational exposure to poultry and prevalence of antibodies against Marek's disease virus and avian leukosis retroviruses. Occup Environ Med. 53:403–410.

Gora A, Mackiewicz B, Krawczyk P, Golec M, Skorska C, Sitkowska J, et al. 2009. Occupational exposure to organic dust, microorganisms, endotoxin, and peptidoglycan among plants processing workers in Poland. Ann Agric Environ Med. 16(1):143–150.

Johnson ES. 1994. Poultry oncogenic retroviruses and humans. Cancer Det Prev. 18:9–30.

Johnson ES, Nicholson LG, Durack DT. 1995. Detection of antibodies to avian leukosis/sarcoma viruses (ALSV) and reticuloendotheliosis viruses (REV) in humans, by enzyme-linked immunosorbent assay (ELISA). Cancer Detect Prev. 19:394–404.

Kleinbaum DG, Kupper LL, Muller KE, Nizam A. 1998. Applied regression and other multivariable methods. 3rd ed. Pacific Grove, CA: Duxbury Press.

Levy BS, Wegman DH, Baron SL, Sokas RK. 2006. Occupational and environmental health. Recognizing and preventing disease and injury. 5th ed. Philadelphia, PA: Lippincott Williams & Wilkins.

Mattsby-Baltzer I, Edebo L, Jarvholm B, Lavenius B. 1989. Serum antibodies to *Pseudomonas pseudoalcaligenes* in metal workers exposed to infected metal-working fluids. Int Arch Allergy Appli Immunol. 88:304–311.

McCullagh P, Nelder JA. 1989. Generalized linear models. 2nd ed. London: Chapman & Hall.

Mehta AJ, Wang XR, Eisen EA, Dai HL, Astrakianakis G, Seixas N, et al. 2008. Work area measurements as predictors of personal exposure to endotoxin and cotton dust in the cotton textile industry. Ann Occup Hyg. 52(1):45–54.

Spaan S, Schinkel J, Wouters IM, Preller L, Tielemans E, Nij ET, et al. 2008. Variability in endotoxin exposure levels and consequences for exposure assessment. Ann Occup Hyg. 52(5):303–316.

Yoo S-J, Choi Y-S, Lim H-S, Lee K, Park MY, Chu C, et al. 2009. Seroprevalence and risk factors of brucellosis among slaughterhouse workers in Korea. J Prev Public Health. 42(4):237–242.